SOLENOID PLUNGER CUSHIONING SYSTEM FOR A WASHING MACHINE BALANCING FLUID VALVE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention pertains to the art of valves and, more particularly, to a solenoid plunger cushioning system for use in a balancing fluid injection valve for selectively dispensing a balancing fluid into a rotating inner tub of a washing machine.

2. Discussion of the Prior Art

During operation of a washing machine, it is not uncommon for an inner tub or spinner, which is rotatably mounted within the washing machine, to become unbalanced due to a particular distribution of a load of laundry. During the course of a typical wash cycle, the inner tub is rotated at a relatively high or extraction speed to extract water absorbed

by the laundry. If the laundry is unevenly distributed within the inner tub during the extraction phase, an out-of-balance condition will develop. This out-of-balance condition, when rotated at the extraction speed, can cause excessive vibration.

Certainly, excessive vibration is detrimental to the continued operation and reliability of the machine. Accordingly, the prior art contains several examples of vibration or out-of balance detection systems for sensing an actual or incipient unbalance condition. In addition, it is known to correct the out-of-balance condition without interrupting operation of the washing machine even after exceeding a predetermined vibration threshold. In general, prior art systems function to reduce the rotational speed of the inner tub, provide a means of re-balancing the inner tub or, less desirably, entirely shut down the machine until a consumer corrects the problem by physically redistributing the laundry within the machine.

Systems for re-balancing an out-of-balance washing machine are well known in the prior art. Examples of such systems are described in U.S. Patent Nos. 3,983,035 and 4,991,247. In each of these systems, the out-of-balance condition is corrected by injecting a balancing fluid into a container located on an inner peripheral portion of a rotating inner tub. Nozzles or other water inlets are adapted to rotate with the inner tub and, upon receiving a particular control signal, dispense a predetermined amount of balancing fluid into the container(s) which eventually counteracts the out-of-balance condition. The structure required to enable each nozzle to rotate with the inner tub, maintain a fluid connection between the nozzles and a central supply, and to provide a separate

supply to each container requires a complicated arrangement of components which substantially increases the cost of the appliance. In addition, it has been found that systems which do not include containers for receiving the balancing fluid on both front and rear portions of the rotating tub require a larger amount of balancing fluid and, moreover, require a longer time period to facilitate correction of the unbalanced condition which could expose the appliance to unacceptable vibration levels.

In addition to the above, there exist a number of complications associated with delivering the balancing fluid to the containers. Specifically, complications exist with controlling the amount of fluid introduced into the containers. When using a pressurized system, precise control of the fluid is difficult to achieve. Namely, when the fluid column is under pressure, it is difficult to accurately control the amount of balancing fluid introduced into the containers. A valve is cycled rapidly and repeatedly to direct the balancing fluid into the rotating inner tub. Rapid opening and closing of the valve must both initially accelerate the balancing fluid and then subsequently stop the forward motion of the fluid stream. When the fluid is under pressure, i.e., when the fluid is brought up from a reservoir located below the container, stopping the forward motion of the fluid stream is often difficult. Once the valve is closed, the fluid develops a tail that extends from the valve until the cohesive bonds within the fluid stream break. This will result in either too much fluid being dispensed into the container or, alternatively, fluid being placed into the wrong container. In either case, correcting the unbalanced state becomes a more difficult and lengthy process.

Typical solenoid valves include a coil having an internal bore, a magnetic pole piece arranged at one end of the bore and a plunger adapted to slide within the bore. Upon activation, the pole piece is magnetized by an electrical current passing through the coil, this in turn draws the plunger back against the pole piece. Without a cushion between the pole piece and the plunger, metal to metal contact will occur which will result in excessive wear, noise and vibration.

In an attempt to overcome this drawback, manufacturers have developed various cushioning devices for the plungers in order to both quiet and extend the operational life of the valve. Typically, plunger cushions take the form of discs, or O-rings mounted on an end of the plunger that are adapted to contact a pole piece within the valve. Unfortunately, the use of solid discs reduced the overall efficiency of the valve. Placing a solid disc between the plunger and the pole piece increased the effective gap between the two components. With this arrangement, an increase in supply voltage was necessary to actuate the valve and hold the plunger in the retracted position. The increased voltage resulted in an increase in heat generated within the solenoid valve which, ultimately, shortened the operational or service life of the valve. In addition, the disc presented a large impact area which caused a rapid deceleration of the plunger and further causes a high force to be applied to the pole piece and remaining valve components, thus reducing the overall operational life of the valve.

Inserting O-rings into a rear portion of the plunger presented different design challenges. When the O-ring contacts the pole piece, air trapped in a center portion of the O-ring acts as a separate cushion, which

can be beneficial in slowing the plunger in a softer way than a disk or solid core. However, the trapped air pressure can become high as the plunger is pulled close to the pole piece and may either leak in an uncontrolled manner or prevent the plunger from coming in contact with the pole piece, again establishing a requirement for a higher current to the coil in a manner similar to that found using a solid disk. The gap between the pole piece and the plunger may still exist and, like the solid disk, requires higher supply voltages and incurs similar service life problems. The high pressure air also serves to rapidly accelerate the plunger away from the pole piece when electrical current is stopped. The rapid acceleration can cause the plunger to move too quickly and strike the valve seat too forcefully, causing bouncing of the plunger and/or excessive wear. A more difficult problem occurs if some air leaks out due to the high pressure. Then, as the electrical current is removed, the plunger begins to move away from the pole piece and the volume within the O-ring, which includes the entrapped air, expands until it begins to create a vacuum since there is now less air trapped than before the leak. The leakage would occur at high pressure, but the drawing of air for replenishment would occur at low pressure or probably not at all. Thus, as the plunger moves away from the pole piece, a vacuum can be formed on the back of the plunger which will retard the movement of the plunger and adversely affect the size and timing of the dollop of fluid being supplied. This effect can be particularly troublesome if the amount of air which leaks out at high pressure is uncontrolled and different from cycle to cycle.

Therefore, while the above described systems for cushioning the solenoid plunger are effective for a variety of application, these systems

would not withstand the rigors associated with rapid and repeated operation associated with an out-of-balance correction system. Accordingly, there still exists a need in the art for a system which will more efficiently dampen the impact the plunger makes on the pole piece without sacrifice the operation life of the valve.

SUMMARY OF THE INVENTION

The present invention is directed to a cushioning system for a solenoid plunger subject to rapid and repeated cycling. More specifically, the solenoid is incorporated into a stationary balancing fluid injector valve for a washing machine having an outer tub, an inner tub rotatably mounted within the outer tub, and an out-of-balance correction system. In a preferred embodiment of the present invention, a plurality of balancing fluid receiving pockets arranged about both front and rear portions of the inner tub. A control unit, upon sensing an actual or incipient out-of-balance condition operates the injector valve to dispense a small amount of balancing fluid into the select ones of the plurality of balancing fluid pockets. Preferably, the washing machine includes two injector valves, a first being associated with the rear portion pockets, and a second being associated with the front portion pockets.

Certainly, injecting balancing fluid from stationary injectors into receptacles arranged about a spinning inner tub requires precise timing. Accordingly, in order to meet these stringent timing requirements, the injector valve must be operated rapidly, and repeatedly in order to achieve proper correction of the out-of-balance condition. Repeated

operation of this type is extremely hard on internal components of the solenoid. Therefore, in accordance with one aspect of the invention, a cushion is mounted to an end portion of the solenoid plunger. In a more preferred form, a groove or annular ring is formed in the end of the plunger and sized to receive a resilient, elastomeric annular ring. Once in place, the annular ring reduces the effects of the repeated impacts between the plunger and a pole piece or end portion of the coil body.

In accordance with another aspect of the invention, the pole piece undergoes a texturing process to roughen the impact surface. Examples of acceptable texturing include cross-hatching, knurling, rough sanding and the placement of grooves in the surface. With this arrangement, a leakage path is provided for air trapped in a center portion of the annular ring. Preferably, leakage of air trapped between the end of the plunger and the pole piece is controlled through the particular distribution and geometry of the texturing applied to the surface of the pole piece. In this manner, deceleration of the plunger, and by extension, greater control of the dispensed balancing fluid is established.

In accordance with a still further aspect of the invention, an electric signal, sent to activate the solenoid is actively controlled through a control unit incorporated into the unbalance correction system. More specifically, the voltage applied to the solenoid coil is ramped or stepped to control the deceleration of the plunger. In other words, the initial activation voltage is held high, then, as the plunger nears the pole piece, the voltage is quickly reduced causing the plunger to slowly impact the pole piece. The control of the supply voltage, in combination with the plunger cushion and texturing of the pole piece, provides for a longer

service life and, in addition, increases control over the injection of the balancing fluid.

Additional objects, features and advantages of the present invention will become more readily apparent from the following detailed description of a preferred embodiment when taken in conjunction with the drawings wherein like reference numerals refer to corresponding parts in the several views.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a plan view of a laundry appliance incorporating an on-axis injection system constructed in accordance with the present invention;

Figure 2 is an exploded view of an outer tub portion of the laundry appliance of Figure 1, showing a balancing fluid and delivery system for the on-axis injection system of the present invention;

Figure 3 is an exploded view of an inner tub assembly depicting rear injection plane fluid receiving pockets for the on-axis injection system of the present invention;

Figure 4 is a perspective view of a back plate of the inner tub assembly of Figure 3 constructed in accordance with a preferred embodiment of the present invention;

Figure 5 is a perspective view of the inner tub of Figure 3 depicting front injection plane fluid receiving pockets arranged in accordance with a preferred embodiment of the present invention;

Figure 6 is a partial cross-sectional view of the on-axis injection system, showing a balancing fluid injector valve and injector nozzle assembly arranged in accordance with the present invention;

Figure 7 is an exploded view of the balancing fluid injector valve of Figure 6;

Figure 8 is a perspective view of an outlet portion of the balancing fluid injector valve of Figure 7;

Figure 9 is a another perspective view of the outlet portion of the balancing fluid injector valve;

Figure 10 is a perspective view of a solenoid valve coil of the balancing fluid injector valve of Figure 7, showing a plunger receiving base and associated pole piece;

Figure 11 is a perspective view of the nozzle assembly incorporated in the on-axis injection system of Figure 6; and

Figure 12 is a partially exploded, detail view of a hub portion of the outer tub, showing a preferred mounting arrangement of the nozzle assembly of Figure 10.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

With initial reference to Figure 1, a laundry appliance constructed in accordance with the present invention is generally indicated at 2. As shown, laundry appliance 2 constitutes a horizontal axis machine including an outer cabinet shell 4 having an associated door 6 which can be selectively opened to expose a washing basket 8. In the embodiment shown, washing basket 8, also referred to as an inner tub or spinner, is mounted within an outer tub 9 (Figure 2) in cabinet shell 4 for rotation about an axis which is angled slightly downward toward a rear portion of cabinet shell 4. For the sake of completeness, inner tub 8 is shown to include a plurality of holes 10, as well as various generally triangular shaped and radially inwardly projecting fins or blades 12 which are fixedly secured to an internal peripheral portion of inner tub 8. In a manner known in the art, inner tub 8 is adapted to rotate during both wash and rinse cycles, such that articles of clothing placed therein actually tumble through either a water/detergent solution or rinse water supplied within inner tub 8. Water for the selected operation is actually contained within outer tub 9 in a manner known in the art. For the sake of completeness, laundry appliance 2 is also shown to include an upper cover 14 for providing access to an area for adding detergent, bleach, softener and the like.

In accordance with one embodiment of the present invention, laundry appliance 2 is shown to include a control panel 16 arranged on an upper rear portion of cabinet shell 4. In the embodiment depicted, control panel 16 includes a plurality of cycle setting buttons 20-22, a start/stop

button 23 and a rotary control knob 24. Buttons 20-22 and control knob 24 are utilized to establish a desired washing operation for laundry appliance 2. Since the general setting and operating of laundry appliance 2 is known in the art and does not form part of the present invention, these features will not be discussed here in detail. However, in general, buttons 20-22 are used to manually set desired operational parameters, including a desired fill level based on load size, wash and rinse temperatures, along with the type of washing operation, such as gentle, normal or the like cycles, typically based on the particular fabrics being washed. On the other hand, control knob 24 is used to set the type and duration of the washing operation. Although control panel 16 is shown to include buttons 20-22, start button 23 and control knob 24, it should be understood that these particular types of control elements are merely intended to be exemplary and that other types of control elements, including electronic control elements, soft touch buttons, a touch screen LED panel and the like could be readily utilized.

Arranged within control panel 16 is a control unit or CPU 39. Control unit 39 includes unbalance detection circuit 41 for detecting actual or incipient unbalanced load conditions occurring within inner tub 8. Typically, during a spin cycle, a particular distribution of laundry within inner tub 8 may lead to an out-of-balance condition when inner tub 8 is rotated at high speed which can generate excessive vibrations of laundry appliance 2. It should be understood that, at this point the details of unbalance detection circuit 41 are not part of the present invention and can actually take various forms, such as that disclosed in commonly assigned U.S. Patent No. 6,422,047 which is hereby incorporated by reference. In any case, unbalance detection circuit 41 receives signals

from an unbalance detecting unit (not shown) and, depending on these signals, provides inputs to tub drive control 44, cycle control 46 and unbalance correction controls 47 which, in turn, provides the control to the on-axis injection system of the present invention as described more fully below.

Referring to Figure 2, laundry appliance 2 preferably includes an on-axis injection system including a balancing fluid storage reservoir 53 having a plurality of side portions 56-59. More specifically, reservoir 53 is integrally molded to an upper region of outer tub 9. Furthermore, a top portion or cover (not shown) extends over side portions 56-59 enclosing reservoir 53 to prevent foreign objects from entering and contaminating the balancing fluid, as well as to prevent fluid loss. With this arrangement, an amount of balancing fluid, preferably in the range of 1-2 gallons, is stored within reservoir 53, with a portion of the balancing fluid being selectively delivered to inner tub 8 upon the detection of an out of balance condition. That is, reservoir 53, inner tub 8 in addition to feed and return conduits (not shown) form at least a portion of a closed balancing fluid containment system so that once filled, additional balancing fluid need never be added to the system. Preferably, the balancing fluid is a mixture of water and a propylene or ethylene glycol solution. More preferably, the balancing fluid is a mixture of water and a salt or calcium chloride solution, or other substances having similar qualities.

In accordance with a preferred embodiment of the present invention, the balancing fluid is delivered to inner tub 8 through a plurality of fluid delivery or receiving channels which are, at least

partially, molded onto a rear portion 60 of outer tub 9. More specifically, as will be detailed more fully hereafter, first and second fluid delivery channels 70 and 71 carry the balancing fluid from reservoir 53 to particular pockets carried by inner tub 8. A third, drain or return channel 73 is further provided on rear portion 60 of outer tub 9 to collect expended balancing fluid from inner tub 8 and ultimately carry the fluid back to reservoir 53 through a hub portion 76. As shown, a plurality of raised wall portions 77-81 extend from hub portion 76 and thereafter separate and define each of the first, second and third channels 70, 71 and 73. Furthermore, in order to reduce the possibility of fluid leaking between first and second delivery channels 70 and 71, a segment of wall portion 81 includes a double wall segment 83. Finally, in addition to partitioning the fluid channels 70, 71 and 73, raised wall portions 77-81 and 83 increase the stiffness and thus the structural integrity of outer tub 9.

In accordance with a preferred arrangement, first and second fluid delivery channels 70 and 71 open to reservoir 53 at respective upper portions 90 and 91. From upper portions 90 and 91, balancing fluid delivery channels 70 and 71 extend along rear portions 94 and 95 of outer tub 9 before opening to delivery channels 99 and 100 at hub portion 76. Preferably, rear portions 94 and 95 are formed with a minimal number of undulations or the like which could lead to inconsistency in balancing fluid delivery. Similarly, a drain opening 105 leads from hub portion 76 to an upper or inner radial portion of drain channel 73. As will be detailed more fully below, as the balancing fluid returns from inner tub 8, it passes along hub portion 76 to drain opening 105 traveling along a rear

portion 106 prior to being returned to reservoir 53 as will be discussed more fully below.

In order to ensure the existence of a proper pressure head, as well as to fully close off the delivery system, a cover plate 120 is secured to raised wall portions 77-81 and 83 on outer tub 9. As shown, cover plate 120 is defined by an outer contour 121 corresponding to raised wall portions 77-81 and includes a notched portion 123 adapted to partially extend about hub portion 76. As further shown in Figure 2, arranged on cover plate 120 are first and second cylindrical receivers 130 and 131. More specifically, cylindrical receivers 130 and 131 are positioned at delivery channels 70 and 71 in order to position one of a pair of balancing fluid injector valves, which are indicated at 135 and 135', within delivery channels 99 and 100 respectively.

Although further details of injector valve assemblies 135 and 135' will be provided hereafter, in general, each of injector valve assemblies 135 and 135' includes at least an outlet or base portion 145 having a curvilinearly tapered end portion 146 adapted to matingly seat in a respective outlet delivery channel 99 and 100, an intermediate portion 147 and a valve coil 148. Most preferably end portion 146 evinces a generally spherical profile that has been truncated. In a preferred form of the invention, injector valve assemblies 135 and 135' are secured within respective cylindrical receivers 130 and 131 through a plurality of raised mounting lugs 155-158 arranged adjacent to each cylindrical receiver 130, 131. More specifically, injector valve assemblies 135 and 135' are secured to mounting lugs 155-158 through respective bracket members 165 by a plurality of mechanical fasteners 170-173. In a more preferred

form, a resilient ring 175 is positioned between valve coil 148 and mounting bracket member 165 to account for any excessive vibrations or misalignment problems with respect to injector assemblies 135 and 135' within outlet delivery channels 99 and 100.

Opening from a lower portion of cover plate 120 is a drain conduit 180 which directs returning balancing fluid from drain channel 73 to reservoir 53. In accordance with a preferred embodiment of the present invention, drain conduit 180 interconnects to reservoir 53 through a pump (not shown) which functions to return the balancing fluid from drain channel 73 to reservoir 53. In accordance with another embodiment of the present invention, drain conduit 180 interconnects with an intermediate sump and pump (not shown) adapted to store the used balancing fluid until demanded through correction controls 47. In any event, it is only important to note that the balancing fluid is preferably returned to reservoir 53 in a manner so as to define a closed system. In this way, there is no further need to add balancing fluid once laundry appliance 2 leaves the factory.

Referring to Figure 3, the on-axis injection system is primarily carried by inner tub 8. In the embodiment shown, inner tub 8 includes a cylindrical spinner body member 190, a back or cover plate 195 and a diverter plate 197 sandwiched therebetween. Spinner body member 190 is preferably formed with a first end defining a rear injection zone 200 and a second end or front injection zone 203. As will be discussed more fully below, a shaft member 204 rotatably supports inner tub 8 within sealed bearings 205-206 (Figure 6). A first plurality of balancing fluid receiving receptacles or rear injection plane pockets 210-217 are arranged

about rear injection zone 200. Each of the plurality of rear injection plane pockets 210-217 is partially defined by a first plurality of raised wall portions, one of which is indicated at 215. In a similar manner, a plurality of front plane diverter channels indicated at 220-223 are partially defined by a second plurality of raised wall portions, one of which is shown at 225. More specifically, front plane diverter channels 220-223 respectively lead to front plane passages 227-230 which, in turn, fluidly interconnect front plane diverter channels 220-223 with a plurality of front plane injection pockets 232-235 (Figure 5) through respective ones of blades 12.

Rear portion 200 of spinner body member 190 is closed off by cover plate 195. As best seen in Figure 4, cover plate 195 includes an inner surface 237 having a plurality of first and second raised wall portions, such as those generally indicated at 239 and 241. In this manner, each of the plurality of rear plane pockets 210-217 and front plane channels 220-223 are isolated one from the other. Additionally, cover plate 195 includes a central opening 250 having a raised rim 253 located on an outer surface 255 (Figure 3) and an inner contour 260 arranged adjacent to central opening 250 on inner surface 237 (Figure 4). Inner contour 260 is formed so as to receive diverter plate 197. Referring to Figure 3, diverter plate 197 includes a plurality of raised portions (not separately labeled) which define a plurality of front panel pathways 265-268 that communicate with channels 220-223.

Referring to Figures 3 and 4, rear portion 200 of spinner body member 190 and inner surface 237 of cover plate 195 include a plurality of raised, baffle portions indicated generally at 270 and 271. As shown,

raised portions 270 and 271 are provided within rear plane pockets 210-217 as well as front plane channels 220-223, and are spaced from both central opening 250 and a central recess 275 of spinner body member 190. Raised portions 270 and 271 form baffles that discourage the sloshing of fluid within rear plane pockets 210-217 and front plane channels 220-223 when spinner body member 190 is revolving at a low rpm. Raised portions 270 and 271 include passages and/or holes (not separately labeled) at the periphery of spinner body member 190 that allow water to flow slowly between volumes formed by raised portions 270 and 271 when cover plate 195 is attached to spinner body member 190. It is desirable to have between 1 and 5 raised portions 270, 271 in each rear plane pocket 210-217 and front plane channel 220-223. The passages through each raised portion 270, 271 should have an area equivalent to round holes of between 1/8 inch and 2 inches in diameter to provide adequate water flow between each rear plane pocket 210-217 and front plane channel 220-223. The most preferred number of baffles is three and the most preferred area is about ¼" equivalent diameter. Similar baffles (not shown) are incorporated into the front plane injection pockets 232-235.

With this arrangement, balancing fluid can be dispensed into any combination of rear and front plane pockets 210-217, 232-235 to compensate for an out-of-balance condition of rotating inner tub assembly 8. With specific reference to Figures 2, 3, 5 and 6, dispensing a dollop of balancing fluid between diverter plate 197 and cover plate 195 near shaft member 204 forces the balancing fluid into one of the plurality of front plane channels 220-223 which lead to passages 227-230 and ultimately to front injection zone 203. Conversely, dispensing a dollop of

balancing fluid between diverter plate 197 and rear zone 200 near shaft member 204 forces the balancing fluid into one of the plurality of rear plane pockets 210-217. The particular pocket 210-217, 232-235 into which the dollop will fall is based on both the sensed need for correction, the injector 135, 135' activated, and the timing of the injection. At this point it should be realized that the actual number of front or rear pockets employed could be varied in accordance with the invention, with the preferred range being between 3 and 12. In any case, by dispensing the dollop of balancing fluid near shaft member 204, the dollop will contact inner tub 8 at a point of low velocity to minimize splash in order to increase the accuracy of the injection.

As will be detailed more fully below, once inner tub assembly 8 ceases to spin, the need for balancing fluid in either rear injection zone 200 or front injection zone 203 is eliminated. Accordingly, as the radial velocity of inner tub 8 decreases, so does the centrifugal force holding the balancing fluid within a particular pocket 210-217 and 232-235. As the force continues to decrease, the balancing fluid begins to migrate to shaft member 204 and collect in recess 275 (Figures 3 and 6) as each respective pocket 210-217 and 232-235 passes a top point of rotation. Once tub assembly slows sufficiently, the balancing fluid travels along shaft member 204 to drain channel 73 and ultimately returns to reservoir 53.

Upon sensing an actual or incipient out-of-balance condition, correction controls 47 signals the on-axis injection system to dispense an out-of-balance correcting balancing fluid into particular portions of inner tub assembly 8. In order to offset the out-of-balance condition, correction

control 47 determines into which plane and into which pocket in that plane an injection of balancing fluid is required. At this point, a timing mechanism (not shown) timely activates one of the pair of injectors 135 and 135' corresponding to the particular injection zone 200 and 203 into which an injection of fluid is necessary. Reference will now be made to Figures 6-9 in describing the preferred construction of injectors 135 and 135'. Since the structure of each injector 135, 135' is identical, a description of injector 135 will be made and it is to be understood that injector 135' has commensurate structure.

In accordance with a preferred embodiment as discussed above, injector 135 takes the form of a solenoid type valve and includes base portion 145 having curved or tapered end portion 146, an intermediate portion 147 and valve coil 148. More specifically, end portion 146 includes a first end defining an outlet opening 283 and a second end having an inner surface portion 286 defining a central recess 288. Extending between outlet opening 283 and an inlet opening 290 is a delivery conduit 292 having a central passage 293. Preferably, delivery conduit 292 is integrally molded to base portion 145 and includes a plurality of tapering rib elements 297-299. More specifically, rib elements 297-299 support delivery conduit 292 and define a balancing fluid inlet or supply opening 305 (Figure 8). Finally, as will be detailed more fully below, a plurality of locating holes, one of which is indicated at 309, are arranged about inner surface portion 286.

In accordance with the preferred embodiment shown, inlet opening 290 is adapted to be selectively sealed through application of a diaphragm 319 positioned along inner surface portion 286. More specifically,

diaphragm 319 includes surface 323 which extends into and seals about central recess 288. As best seen in Figure 8, a sealing member 327 is centrally arranged on surface 323 and positioned to selectively close off inlet opening 290 through axial movement of a plunger 335 which is fixed to diaphragm 319.

More specifically, as best shown in Figure 7, plunger 335 includes a first end portion 336 interconnected to diaphragm 319, and a second end portion 337. As best seen in Figure 9, second end portion 337 includes an annular notch or groove 339 within which is arranged a cushioning ring 340. Cushioning ring 340 is provided to reduce the effects on valve assembly 135 from the repeated cycling of plunger 335. In a typical solenoid valve operation, plunger 335 is drawn into a cylindrical bore 343 that extends within valve coil 148 (Figure 10). Each time plunger 335 enters bore 343, second end 337 of plunger 335 is forced against a pole piece or end stop 344.

Experience has shown that repeated operation of the valve results in wear to both second end 337 and pole piece 344 causing the calibration of valve assembly 135 to exceed manufacturer specifications. However, by incorporating cushioning ring 340 into second end portion 337, the life of valve assembly 135 can be extended such that prolonged operation is possible. In addition, cushioning ring 340 helps control the physical profile of the balancing fluid dollop as it passes from outlet 283. Because of the critical role that cushioning ring 340 plays in the performance of valve assembly 135, it would generally be considered desirable to have pole piece 344 as smooth as possible to minimize wear on cushioning ring 340. However, each time cushioning ring 340 contacts pole piece

344, an amount of air is trapped within a center portion 345 of cushioning ring 340. Because the force between pole piece 344 and plunger 335 becomes large as plunger 335 approaches pole piece 344, the pressure of the trapped air can become high and air may leak from the center of cushioning ring 340 in an uncontrolled manner.

When the electrical power to valve coil 148 is removed, plunger 335 moves away from pole piece 344. If air has leaked from the center of cushioning ring 340, then a vacuum may be drawn within cushioning ring 340 to retard or prevent the movement of plunger 335, which undesirably changes the amount and location of the injected fluid. In order to alleviate the problem of trapped air, pole piece 344 is subject to a texturing process wherein the surface of pole piece 344 is formed with channels, notches, grooves, or the like. With this arrangement, trapped air can escape from center portion 345, thereby enabling plunger 335 to fully retract into bore 343 without excessive pressure build-up. Further, the texturing provides a path for air to reenter center portion 345 as plunger 335 is released so that vacuum does not retard plunger motion. It should be understood that a polished pole piece may work satisfactorily for some applications, but where cycle-to-cycle consistency is desired, a roughened or textured pole piece 344 offers more consistent performance. Finally, a coil spring 348 is arranged about plunger 335 to bias diaphragm 319 against inlet opening 290 during periods of inactivity.

In another arrangement, the operational life of valve assemblies 135 and 135' is increased by ramping the supply voltage to valve coil 148. More specifically, an initial activation voltage, which causes plunger 335 to begin to retract into bore 343, is maintained at slightly higher than

normal levels for a period of, for example, 0.2 seconds. However, once plunger 335 begins to move, the supply voltage is gradually reduced in a ramp-like function to cause plunger 335 to gradually retract into bore 343. At this point, the voltage is slightly higher than the holding voltage for valve coil 148. In other words, the voltage is at a level slightly higher than needed to hold plunger 335 in a retracted position. Alternatively, in a place of gradually ramping down the voltage, the voltage is reduced in the form of a step function causing a rapid or sudden change in the applied voltage. This control of the supply voltage, possibly in combination with plunger cushion ring 340 and the texturing of pole piece 344, results in a more accurate dispensing control, as well as provides an increase in the service life of valves 135 and 135'.

With further reference to Figures 7-9, intermediate portion 147 of valve assembly 135 has a first side surface 355 and a second side surface 356 between which extends a central opening 358. More specifically, first and second side surfaces 355 and 356 are surrounded by a cylindrical side wall portion 360. Intermediate portion 147 is fitted to base portion 145 with an annular notch or groove 362, which is adapted to receive a sealing ring 364, being defined between base portion 145 and cylindrical side wall portion 360. Actually, sealing ring 364 projects radially outwardly of cylindrical side wall portion 360. With this arrangement, sealing ring 364 maintains a fluid tight seal about injector 135 within cylindrical receiver 130 (Figure 6). Therefore, valve assembly 135 will seat within receiver 130 despite differences resulting from manufacturing tolerances. In the embodiment shown, sealing ring 364 constitutes a resilient O-ring, however, it should be understood that various ring profiles can be used to obtain the same result. In addition, arranged on

first side surface 355 are a first plurality of locating pins, one of which is indicated at 366. Each locating pin 366 is adapted to extend into a respective locating hole 309 of base portion 145 for positioning intermediate portion 147 in a particular alignment with base portion 145. Similarly, a second plurality of locating pins 368 project from second side surface 356. The second plurality of locating pins 368 are adapted to engage into a respective notch portion 375 (Figure 10) on valve coil 148 to maintain a particular alignment between intermediate portion 147 and valve coil 148.

Valve assemblies 135 and 135' are selectively activated though application of voltage to electrical terminals 380 and 381 (Figure 7) of valve coil 148. Referring to Figures 3 and 6, upon determining into which injection zone 200 or 203 and, more importantly, into which pocket(s) 210-217, 232-235 in that zone the balancing fluid is to be injected, control 47 times the activation of a particular injector 135, 135' to deliver the balancing fluid necessary to offset the out-of-balance condition. Upon activation, plunger 335 is drawn into valve coil 148 exposing inlet opening 290 to a flow of balancing fluid from supply opening 305. In accordance with the invention, the voltage applied to activate valve coil 148 can be ramped, stepped or spiked to enable control over the movement of plunger 335 and, by extension, the amount of fluid dispensed. For example, an initial spike from zero to approximately 18 volts can be applied. Thereafter, the voltage would be reduced to, for instance, 8 volts. This reduction could be performed in one or more steps. Preferably, the reduction is ramped over approximately 1-2 milliseconds from 18 volts to 8 volts. However, a multi-stage reduction from, for instance, 18 volts to 12 volts and then to 8 volts could be

employed. In any event, the balancing fluid travels through central passage 293, passes from outlet opening 283 and flows through a respective gap or passage, one of which is indicted at 396, into a nozzle assembly 400 which dispenses the balancing fluid into the desired pocket 210-217 or 232-235. Preferably passage 396 is in the range of 1/4"- 1" and, more preferably, from 3/8"-1/2".

As best seen in Figure 11, nozzle assembly 400 is defined by an arcuate main body portion 403 having a first surface 405, an opposing second surface 406 and surrounding side surface portions 408-411. In accordance with a preferred form of the present invention, first and second fluid inlet ports 420 and 421, each having a respective raised side portion 422 and 423, are arranged on first surface 405. More specifically, raised side portions 422 and 423 provide a flange which help locate nozzle assembly 400 on hub 76 and further assist in sealing nozzle assembly 400 to passage 396. Inlet ports 420 and 421 open to respective nozzle elements 430 and 431, each having an outlet 433, 434 which extends from second surface 406 into a respective front or rear injection zone 203 or 200 respectively. Each outlet 433, 434 opens substantially perpendicular to a respective passage 396 and defines a sharp internal edge orifice (not separately labeled) which enables the low pressure system to cause a particular dollop of balancing fluid to remain cohesive when being dispensed. In addition, this arrangement also causes each dollop to have a clean break on the back portion thereof and minimizes follow-on droplets which could reduce the accuracy of the injection and may result in water placement outside a desired pocket 210-217, 232-235. The internal edges of passages 423 and 434 are considered sharp when their length perpendicular to passage 396 is less than 1/8", preferably less

then 1/16" and, most preferably, less than 0.030". The sharp internal edge of passages 423 and 434 preferably have a radius of up to 0.010". Finally, as will be detailed more fully below, nozzle assembly 400 includes a pair of locating pins 440 and 441, as well as a plurality of mounting apertures 450-452 arranged along first surface 405.

Referring to Figure 12 which depicts a preferred mounting arrangement of the present invention, nozzle assembly 400 is secured to an inner surface 469 of hub portion 76 through a plurality of mechanical fasteners 476-478. As shown, a corresponding pair of locating holes 480 and 481 are arranged along a portion of inner surface 469 to receive a respective locating pin 440, 441 which position and align nozzle inlets 420 and 421 with respective outlets 484 and 485. Fasteners 476-478 are actually received in a plurality of threaded bores 490-492 provided on inner surface 469.

Upon sensing an unbalanced condition of inner tub 8, unbalance detection circuit 41 in CPU 39 determines the magnitude and location of the unbalanced condition. At this point, correction control 47 calculates the amount of balancing fluid, and into which one of the plurality of pockets 210-217 and 232-235 to inject the balancing fluid to offset the unbalanced condition. More specifically, a timing mechanism (not shown) monitors the position of the inner tub 8 relative to injectors 135 and 135'. Through use of the timing mechanism, unbalance correction control 47 operates the appropriate one of injectors 135 and 135', at a proper time and for a desired duration, to dispense the calculated amount to fluid into the requisite pocket 210-217, 232-235. Centrifugal force, generated by rotating inner tub 8, forces the balancing fluid into the

appropriate one of the plurality of pockets 210-217, 232-235. This process repeats itself until the unbalance condition is corrected as sensed by unbalance detection circuit 41. As indicated above, once the centrifugal force keeping the balancing fluid within the particular pocket 210-217, 232-235 diminishes sufficiently, the balancing fluid, under force of gravity, returns to drain channel 73. As shown in Figure 12, this return flow is accomplished with an inner surface 469 of hub portion 76 being provided with at least one return port indicated at 500. In this manner, the balancing fluid is ultimately returned to reservoir 53 for continued use as required by unbalance control 47.

As shown in Figure 12, injectors 135 and 135' are located on one side of hub portion 76. Although the precise location of injectors 135 and 135' is not critical, it is important that they be placed on the side of machine 2 where the spinner rotation produces a downward motion. In this way, the balancing fluid is injected at a location where the maximum time is available for the fluid flow to the periphery of spinner 8 before the appropriate pocket 210-217, 232-235 passes over the top of machine 2. If nozzles 135 and 135' are not placed on the downward moving side, some fluid may not traverse to the outside of spinner 8 where centrifugal force is maximum and may fall back out of a respective pocket 210-217, 232-235 when spinner 8 is moving more slowly, such as during an initial balance process.

Although described with reference to a preferred embodiment of the invention, it should be readily understood that various changes and/or modifications can be made to the invention without departing from the spirit thereof. For instance, the cushioning valve system could be

employed in other environments, such as a water fountain, without departing from the scope of the present invention. In addition, while the texturing is depicted as a plurality of bisecting groves formed on the pole piece, the grooves could take on a variety of different geometries, such as random cross hatching, spiral grooves, circular notches and the like applied through a variety of processes including sanding, grit blasting, knurling, etching and the like. In general, the invention is only intended to be limited by the scope of the following claims.